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Analysis of the Chinook salmon populations of lakes Huron and Michigan, 1985-2004

Report from:

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Introduction

Salmonids play an important role in the ecosystems of lakes Huron and Michigan. In particular, Chinook salmon *Oncorhynchus tshawytscha* were introduced in 1967 to help control exotic forage fishes, particularly alewife *Alosa pseudoharengus* and rainbow smelt *Osmerus mordax*. Chinook salmon have supported valuable recreational fisheries in both lakes for over 25 years and have significantly suppressed alewife and rainbow smelt populations in both lakes. Harvest was once a highly correlated function of stocking levels; however, more recent trends in harvest in neither lake can be explained by stocking levels alone.

In 1987-90, Chinook salmon in Lake Michigan experienced a noticeable disease epizootic and significant decline in abundance, possibly resulting from increases in natural mortality brought on by nutritional stress. In 1999, Chinook stocking in Lake Michigan was reduced in hopes of minimizing risk to the fishery associated with instability in Chinook survival (Figure 1).

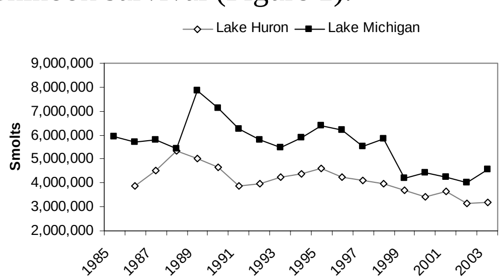

Figure 1. Chinook salmon stocking, all agencies, lakes Huron and Michigan.

Interestingly, there was little if any evidence of the disease epizootic in Lake Huron during this time period. Stocking levels in Lake Huron had been rising through the 1980's. Partly in response to the Lake Michigan experience, the Lake Huron Committee chose to freeze lakewide Chinook stocking levels at approximately 4.0 million smolts in 1991. In spite of reduced stocking, Chinook growth and condition in 1997 approached the low values measured in Lake Michigan during its epizootic outbreak of the mid 1980s. Consequently, the Lake Huron Committee implemented a 20% reduction in Chinook stocking in 1998. The stocking reductions in both lakes were intended to minimize risk to fisheries and to the fish communities associated with instability in Chinook survival (Figure 1). Low survival of Chinook salmon could lead to loss of economically valuable recreational fishing opportunity for the species and inadequate control of alewives and other prey, with potentially negative implications to native species.

The Lake Michigan Technical Committee Salmonid Working Group (SWG) has been exploring biological and fishery indicators that might prove useful in evaluating the effects of stocking changes and, specifically, early detection of Chinook salmon population stress. These indicators were originally referred to as the "10 Red Flags". In 2003 and 2004, recreational fishery data for Chinook salmon suggested that growth and condition factors declined further in Lake Huron to levels below those ever measured in Lake Michigan. In 2004, Lake Huron's alewife population showed signs of a collapse from preliminary results from fall USGS hydroacoustic and bottom trawling surveys. As a consequence of the alewife collapse and record low condition and growth of Lake Huron Chinook salmon, the Michigan Department of Natural Resources Fisheries Division (MiDNR) chose to engage in a "Red Flags" analysis of both lakes, using the criteria to assess the condition of Lake Huron's Chinook population with respect to Lake Michigan's. Some of the "Red Flags" evaluated for Lake Michigan were never measured in Lake Huron, but for most criteria, data were available from both lakes. Herein, the Lake Huron Technical Committee (LHTC) and the SWG report trend analysis of selected indices to describe the status of the Chinook salmon of both lakes Michigan and Huron. These data and associated model output will be used to assist managers in making decisions on stocking and harvest management strategies.

Methods

Data included in the report were provided by several agency and university sources. Members of the SWG and LHTC collaborated in collection and consolidation of data. The time series of most data began in 1985 for Lake Michigan and 1986 for Lake Huron. There were years with missing values where data were either not collected or are not yet available. The primary measures of Chinook population dynamics are: 1) harvest, as measured by coordinated lake-wide surveys in Lake Michigan and harvest surveys at standard index ports on Michigan waters of Lake Huron, and weir harvest, 2) indices of abundance, as measured by recreational catch rates and surveys, and returns of marked cohorts, 3) reproduction, 4) growth, as measured in survey data where available and from biological data from MiDNR's July and August creel surveys, which now represent a sample size of more than 20,000 Chinooks (12,272 Lake Michigan, 8,427 Lake Huron), 5) ration from surveys on Lake Michigan (lake trout ration was used to represent Lake Huron where survey data for Chinook are lacking), 6) prey abundance from USGS and interagency assessments, 7) pathogen prevalence and other indications of health, 8) age composition from creel and fishery-independent surveys, 9) environmental conditions, and 10) others.

Results

1. **Harvest**: Lake-wide recreational harvest levels were highest during 1985-1987 in Lake Michigan and declined dramatically during 1989-1995 (Figure 2). Harvest recovered after 1995 and has reached average harvest levels of the mid 1980's. Lake Huron's harvest at the 9 index ports rose from 1992-1997 and the 1997 harvest was 2.8 times the 1992 level. Harvest declined from 1998-2001, but increased in 2002 and now appears to be declining again (Figure 2).

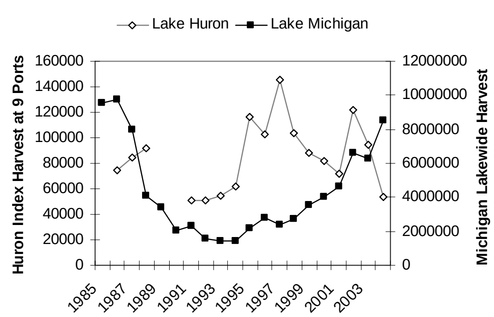

Figure 2. Chinook salmon harvest (number) from 9 index ports in Lake Huron and estimated lakewide harvest (pounds) in Lake Michigan.

Total weir harvest for Lake Michigan, representing the composite of all weirs (Figure 3), was variable in the 1980s, relatively low but stable in the mid-1990s, and has been increasing since 2000. While returns to Lake Michigan weirs appears to be increasing, harvest at Lake Huron's Swan Weir has declined steadily since 1992; its lowest harvest was only 6,193 fish in 2004 (Figure 3).

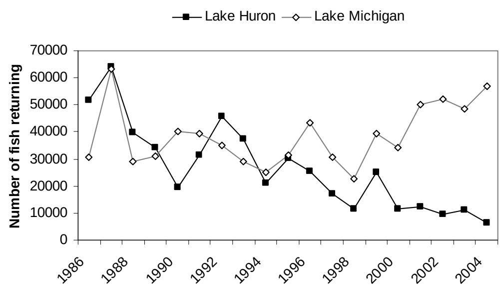

Figure 3. Comparison of weir harvest (numbers of fish) in Lake Huron (Swan River) and Lake Michigan weirs.

2. **Indices of Abundance**: Although recreational harvest levels in Lake Michigan have almost recovered to those of the mid-1980's, catch rates have climbed sharply in 2003 and 2004 suggesting that current harvest may not be sustainable (Figure 4).

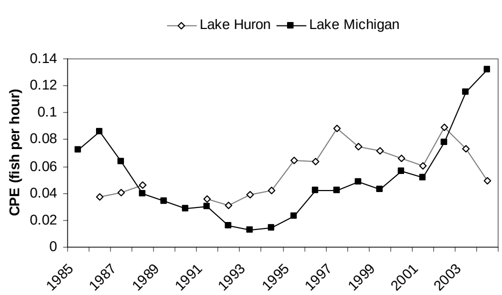

Figure 4. Chinook salmon recreational catch rates (number of fish per hour) for lakes Huron and Michigan.

The recent rise in catch rate is unexpected considering that stocking was reduced in 1999. Similar to Lake Michigan, catch rates in the Lake Huron recreational fishery rose to record levels in recent years despite reductions in stocking (Figure 4). While catch rates in the recreational fishery have generally risen, returns of coded-wire tags released at Lake Huron's Swan Bay have declined steadily, paralleling the decline in harvest at Swan Weir. These results suggest that the declines in harvest and catch rate of fish stocked at Swan Creek was caused by density-dependent affects from substantial numbers of wild Chinooks in Lake Huron.

3. **Natural Reproduction**: Reproduction has been estimated for some years and not for others in both lakes using various methods. Based on oxytetracycline (OTC) marking rates on vertebrae sampled from both lakes during 2004, reproduction contributed 86% or more of recruitment of the 2001-2003 year classes in Lake Huron; whereas OTC estimates of natural reproduction in Lake Michigan were 34%, 54%, and 65% for the 2001, 2002, and 2003 year classes, respectively (Figure 5).

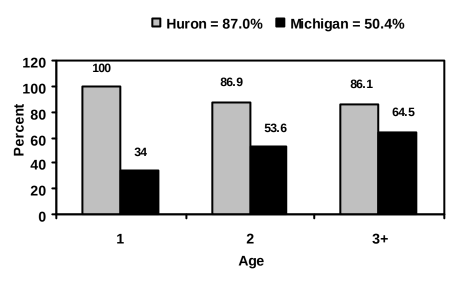

Figure 5. Percent of Chinook salmon sampled in 2004 estimated to be from natural recruitment for lakes Huron and Michigan, based on incidence of fin clips and oxytetracycline marks on vertebrae.

Based on previous OTC marking studies, reproduction in Lake Huron has increased from approximately 15% of recruitment in the early 1990's to near 80% in 2000-2003. Lake-wide estimates of wild smolt production based on fin clip and oxytetracycline incidence was approximately 0.75 million in 1992-1995, but as high as 12 million in 2000-2002 (Figure 6).

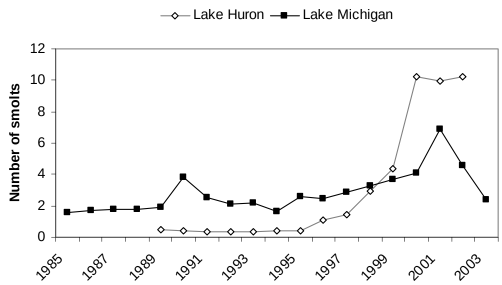

Figure 6. Estimated number of wild Chinook salmon smolts in lakes Huron and Michigan.

For Lake Michigan, annual production of wild Chinooks from 1985-2004 has ranged from 1-6 million smolts with an average production of approximately 2.5 million lakewide; an amount equal to approximately ½ the current number of fish stocked (Figure 6).

4. Measures of Growth: Chinook weight-at-age varied by data source (as expected), and also by year, suggesting variation in growth conditions over time which are presumably related to Chinook density, prey availability, and environmental conditions such as water temperature. Weight at age 3 of recreationally caught Chinooks appeared to increase in Lake Michigan following the 1987-88 decline in Chinook abundance and concurrent production of strong 1987-88 alewife year classes (Figure 7). Lake Huron weights paralleled those of Lake Michigan through 1991, but were significantly lower than Lake Michigan's thereafter (Figure 7).

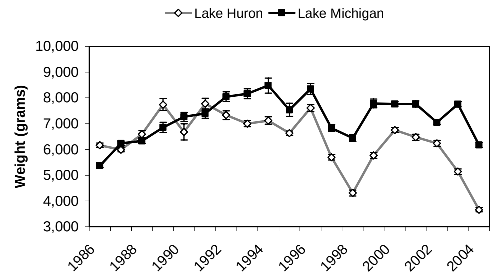

Figure 7. Chinook salmon weight-at-age- 3 from recreational harvest (July-August) for lakes Huron and Michigan.

Weight-at-age 3 declined in both lakes during 1996-1998 following declines in adult alewives, then recovered rapidly as an exceptionally large 1998 alewife year class recruited to both lakes. Since 1999, Lake Michigan age-3 Chinooks have varied little in weight, averaging 7.6 kg. Lake Huron age-3 Chinooks, on the other hand, averaged 6.1 kg since 1999 and declined to only 5.1 kg in 2003. MiDNR Master Angler awards (fish caught from the sport fishery in Michigan waters that are over 27 pounds) declined after 1991 in Lake Huron, where they have averaged 4 per year since 1998. Master Angler awards were variable in Lake Michigan between 1988 and 2003, averaging 96 per year, then fell to only 6 in 2004 (Figure 8).

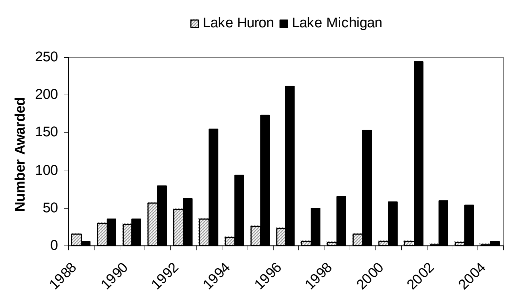

Figure 8. Number of Master Angler Awards (catch and keep category), lakes Michigan and Huron.

5. Ration: Mean ration by age from Lake Michigan Chinook salmon collected in the open-water survey has varied for age-1 and -2 fish, but less so for age-3 Chinooks (Figure 9).

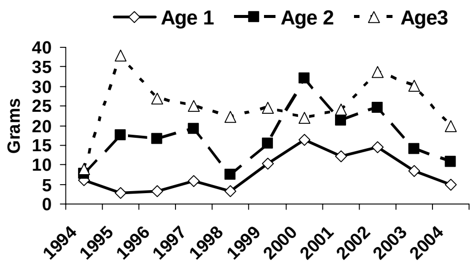

Figure 9. Trends in Chinook salmon ration by age group, Lake Michigan.

Alewives contribute to >85% of the ration by weight for all age groups examined in Lake Michigan. For age-1 and -2 fish, ration increased from 1998 to 2000 following a strong 1998 year class of alewives. Ration for all age groups decreased in 2003 and 2004, probably as a function of demise of the strong 1998 year class of alewives (Figure 9).

Similar to Lake Michigan, Chinook are the major consumers of alewife in Lake Huron (Figure 10). Ration was only measured in 1997 and 1998 in Lake Huron, but there are long-term diet data available for lake trout. From 1976-1987, alewives and rainbow smelt were co-dominant in the Lake Huron lake trout diet, but alewives became the principal prey thereafter, at least until 2003 (Figure 11).

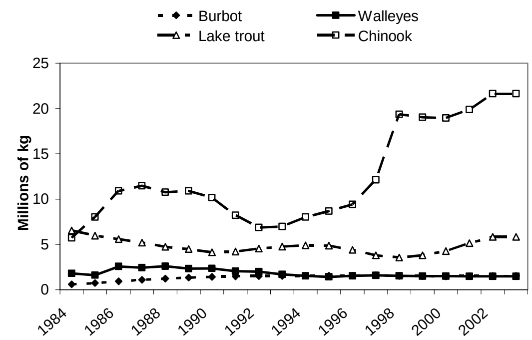

Figure 10. Predicted consumption of alewives by four predator fish, Lake Huron, estimated using Lake Huron Consumption-Production Model. Predator energy densities and alewife composition of diets for 1999-2003 were estimated using 1996-1998 data.

In 2003, rainbow smelt replaced alewives as the dominant prey item and other species, particularly round gobies, became more prominent. Percent of void stomach varied without trend in the early portion of the time series, increased sharply in 1997, recovered in 1999-2002, and then rose to the highest levels yet observed in 2003 and 2004 (Figure 11).

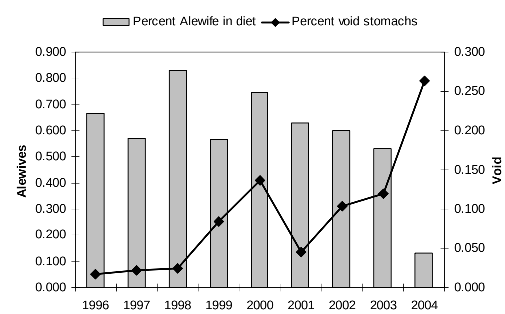

Figure 11. Trends (percent) in alewife composition and incidence of void stomachs, lake trout, Lake Huron.

6. **Forage abundance**: Lake-wide biomass of “adult” (age 1 and older) alewives in Lake Michigan has been declining since 2002 (Figure 12). In addition, the condition of Lake Michigan

alewives dropped by about 15% between the 1984-1994 and 1995-2001 time periods.

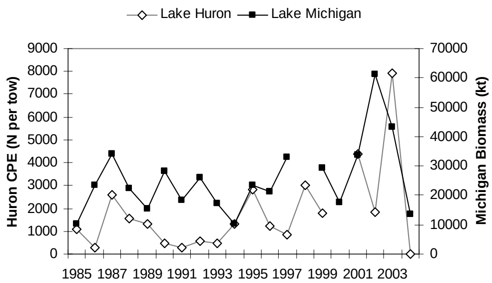

Figure 12. Fall bottom trawl CPE for alewives, Lake Huron and alewife biomass (age1+) for Lake Michigan.

The drop in condition was likely due to decreased availability of *Diporeia* in the diet of alewives beginning in 1995 and/or benthification of the foodweb caused by dreissenid colonization. Preliminary data from determinations of caloric density in alewives has indicated that caloric density of Lake Michigan alewives has declined by about 35% between the 1984-1994 and 1995-2002 time periods. The decline in abundance and drop in caloric density in alewives likely explains the trends in Chinook salmon growth in Lake Michigan.

Although no similar studies of caloric density were conducted in Lake Huron, it appears almost certain Lake Huron's alewives were similarly affected. Zebra *Dreissena polymorpha* and quagga *Dreissena bugensis* mussels, in combination, principally inhabit depths less than about 46 m. A large proportion of the main basin of Lake Huron is less than 46 m, and therefore prime habitat for dreissenid colonization. Dreissenids are increasing in Lake Huron, but at a slower rate than they did in Lake Michigan.

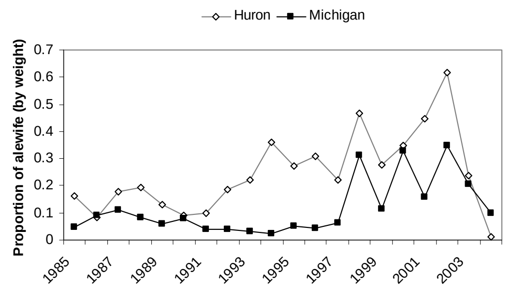

Figure 13. Proportion of bottom trawl catches composed of alewives by weight.

The prey base of Lake Huron has been alternately dominated by smelt and alewives throughout the time series. From 1993-2002, the proportion of the combined catch composed of alewives rose to 35.5% (Figure 13). During this period, alewives became the principal prey of salmonids. In 2003, however, Lake Huron's alewife population entered a period of collapse. By fall of 2004, the Lake Huron alewife population was estimated to be near zero, based on both fall bottom trawl and hydroacoustic-midwater trawl estimates. The fall bottom trawl alewife CPE was only 15; compared with the 1973-2003 average of 1,632. Low numbers of alewives were sampled only in the southern portion of the main basin; nearly all were young of year. Exceptionally strong 2001 and 2003 year classes appeared to sustain heavy mortality during the winters of 2001-2002 and 2003-2004 respectively. We suspect that these year class failures were caused by a combination of consecutive harsh winters, rising predation levels caused by wild recruitment of Chinook salmon, and food web shifts possibly attributable to dreissenid colonization. For all practical purposes, alewives ceased to contribute to the prey base of Lake Huron in 2004. Rainbow smelt recruitment remains strong and smelt catch rates rose somewhat in the fall bottom trawl index in 2004. Likewise, there was evidence of significant bloater chub recruitment in 2003 and 2004. Modest increases in smelt and bloater in 2004 were not sufficient to compensate for the near disappearance of alewives. The USGS bottom trawl survey suggests that prey biomass in Lake Huron was the lowest of the time series in fall 2004 and that prey biomass declined by 65% between 2002 and 2004 (Figure 12).

The prognosis for Lake Michigan differs from that for Lake Huron. No year class produced after the 1998 year class was nearly as strong in Lake Michigan. The 1998 year class has almost been depleted and thus we would expect the decline in alewife biomass measured in 2004. Despite the recent decline, alewife biomass remains slightly below the long-term average (Figure 12). Recruitment of alewives from the 2004 year class appears to be comparable to the average recruitment assuming good over-winter survival. The combined effects of declining numbers of older, larger alewives, strong recruitment, and lower caloric density should cause growth and condition of Chinook salmon in Lake Michigan to decline to near or just below long-term averages in 2005. In Lake Huron, on the other hand, owing to the near disappearance of alewives, we expect Chinook growth and condition to be lower and Chinook distribution to be quite different than anything experienced prior to 2004.

7. **Fish health:** The prevalence of *Renibacterium salmoninarum* (*R.s.*, causative agent for bacterial kidney disease [BKD]) has been evaluated using kidney smears with various methods in both lakes. BKD was apparently low for the period 1982-1986, but after 1986, the numbers of fish which tested positive rose dramatically. With pathogen levels high, there were also high levels of gross clinical signs of disease. Chinook salmon in Lake Michigan experienced high mortality attributed to BKD. After 1990, the percent of fish testing positive using visual signs of disease started to decline (Figure 14).

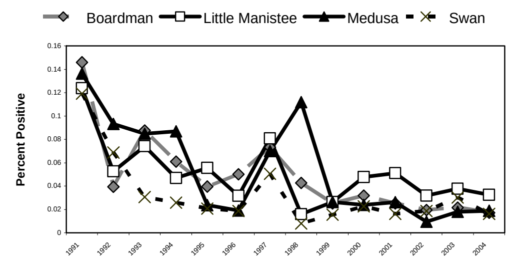

Figure 14. Trends in visual signs of disease from Michigan DNR weirs on lakes Huron and Michigan.

In recent years, visual signs of the disease were low in both weir and vessel samples, in both Lake Huron and Lake Michigan (Figure 14).

As with growth, condition factors [Ktl = (weight (gm)/total length (mm)^3) X 10^5] from the Chinook recreational catch of the two lakes paralleled each other until 1991, but were significantly different from each other thereafter. Lake Michigan's Chinook salmon Ktl varied with a mean of 1.08 and declined to 1.0 in 2004. Lake Huron's Ktl, on the other hand, declined steadily from a value of 1.14 in 1991 to 0.90 in 1998. Condition recovered in response to increasing prey availability (strong 1998 alewife year class) in 1999 but declined again in 2003 to 0.92 and in 2004 to 0.84 (Figure 15).

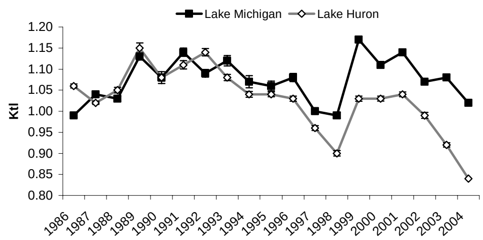

Figure 15. Trends in condition factor for recreationally-caught Chinook salmon, lakes Michigan and Huron.

Data are available from as early as 1973 for mature Chinook salmon escaping to the AuSable River, tributary to central Lake Huron. From 1973-1981, Ktl of AuSable Chinooks averaged 1.248, but sampling was interrupted from 1982-1995 and resumed in 1996. From 1996-2002, Ktl averaged only 0.966; significantly less than the earlier era. Ktl again fell significantly in both 2003 and 2004, to 0.893 and 0.834, respectively. Five especially lean (average Ktl = 0.638) AuSable River area Chinooks, although not showing visual signs of BKD, proved to be carrying very high levels of the disease organism (Mohamed Faisal, Michigan State University, personal communication). In 2004, 12% of escapement Chinook salmon from Lake Huron sampled from the AuSable River and Swan Weir had condition factors of 0.75 or less. Some such Chinooks may have been succumbing to malnutrition prior to spawning. Chinook condition factors could decline even further in 2005 as a consequence of Lake Huron's alewife collapse.

8. **Age composition:** In Lake Huron, contribution of age-2 Chinooks to the recreational catch has risen from near 20% in the mid 1980's to 50% in 2003 (Figure 16).

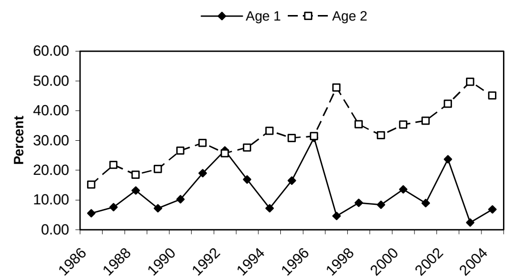

Figure 16. Trends in age composition for age 1 and 2 from the recreational catch of Chinook salmon, Lake Huron.

The increase in age-2 catch appears to have been at the expense of age-4 Chinooks, which declined from 31% in the 1980's to 2.6% or less in 2002 and 2003 (Figure 17).

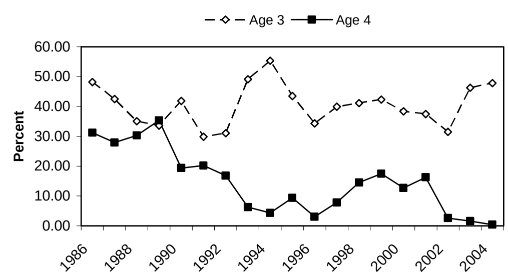

Figure 17. Trends in age composition for age 3 and 4 from the recreational catch of Chinook salmon, Lake Huron.

A similar, but less pronounced pattern in age 1 and 2 fish and declining returns at age 4 was seen in Lake Michigan (Figure 18 and 19). Age-4 Chinooks only contributed 4.9% and 2.8% of the Lake Michigan recreational catch in 2002 and 2003, respectively. Age 2 and 3 fish make up a majority of the fish in the recreational harvest for both lakes.

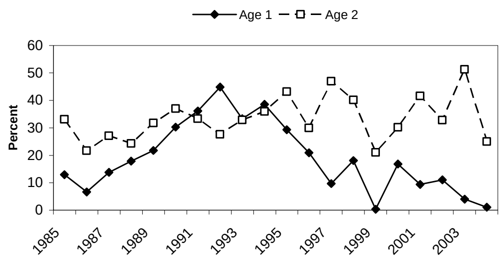

Figure 18. Trends in age composition for age 1 and 2 from the recreational catch of Chinook salmon, Lake Michigan.

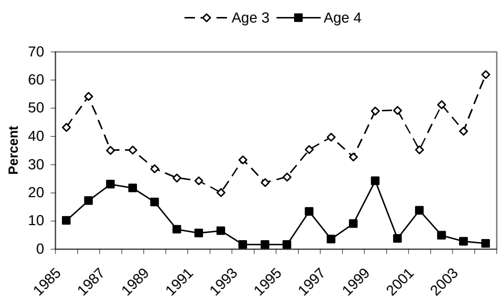

Figure 19. Trends in age composition for age 3 and 4 from the recreational catch of Chinook salmon, Lake Michigan.

9, 10**. Other indices**: Net migration between lakes Michigan and Huron, based on coded-wire tag returns, has been relatively low in most, but not all years (Figure 20).

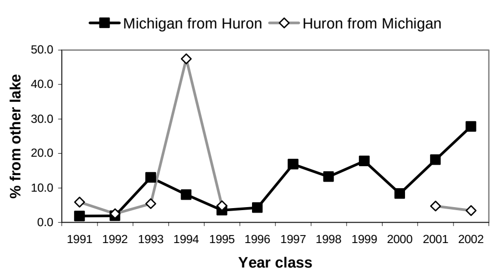

Figure 20. Percent of coded-wire tagged Chinook stocked in one lake but caught in the other (straying).

Nearly 50% of Chinook salmon of the 1994 year class stocked with coded-wire tags in Lake Michigan were returned from Lake Huron. Over 20% of the 2001 and 2002 year classes stocked with coded-wire tags in Lake Huron have, to date, been returned from Lake Michigan. Evidently, Chinook salmon migrate between lakes more in some years than in others but causes of the variation are unclear. It is hypothesized that the net migration toward Lake Michigan for the 2001 and 2002 year classes was caused by the greater availability of prey in Lake Michigan. If migration by the coded-wire tag lots is representative of all Lake Huron's Chinooks of those year classes, the total number of Chinooks of Lake Huron origin presently in Lake Michigan could be substantial.

<ins>Summary</ins>

Based upon the LMTC SWG indicators, the Lake Huron Chinook population is experiencing unprecedented (in the collective Great Lakes experience) nutritional stress. Lake Michigan's Chinooks are showing signs of stress, but most parameters remain near or slightly below the long-term average. The Chinook salmon populations of lakes Michigan and Huron were remarkably similar in terms of growth rates, condition factors, and age compositions in the late 1980's. After about 1992, however, estimates of these parameters diverged for the two lakes, with Lake Huron's fish showing declining tends in growth and condition. Lake Michigan's growth rates and condition factors increased during the early 1990's, probably as a result of a BKD epizootic-induced reduction in Chinook salmon density. The epizootic did not manifest itself in Lake Huron, although Chinooks were frequently found to be carriers of the disease. Sometime after 1994, Chinook salmon reproduction in Lake Huron appears to have increased and reproduction contributed over 80% of recruitment by 2000. Thus, while disease had reduced the density of Lake Michigan Chinooks, Lake Huron Chinook salmon populations were increasing in density from rising rates of natural reproduction. The declines in Lake Huron's growth and condition were likely a function of density-dependent mechanisms. This likely led to a substantial rise in predation rates which accounted for a decline in the mean age of alewives in Lake Huron during the 1990's. The shift in energy flow to the benthic community caused by dreissenid colonization, combined with two colder than usual winters (2002-2003 and 2003-2004), caused alewife production and recruitment to decline. The combined rise in predation rates and food web shift in favor of benthic production led to collapse of Lake Huron's alewives in 2004. Reproduction rates in Lake Michigan (approximately 50% natural recruitment) appear to be much lower than in Lake Huron. On average, Lake Michigan tends to produce a higher biomass of alewives which is possibly a function higher pelagic productivity. Nevertheless, recent studies by NOAA have shown that dreissenids have had negative impacts on the food web in Lake Michigan by causing declines in zooplankton production in nearshore areas. Lake Michigan's Chinook growth rates declined in 2003 and 2004, but remain higher than in Lake Huron. Alewife biomass declined in 2004, but also is substantially higher compared to Lake Huron and only recently fell below the long-term average. Based on midwater trawls and Chinook salmon diets, alewife age distribution in Lake Michigan remains fairly robust with at least four year-classes present.

Future Direction:

Our results suggest that Chinook salmon have effectively reduced the population of alewives to record low levels since their introduction in the upper Great Lakes. Uncertainties such as whether or not Lake Michigan will follow the path of Lake Huron and experience a total collapse of its alewife population remain. Other questions raised by our comparison of the two lakes include: Will the Lake Huron prey base recover and reach a balance between predators and prey?; How will Lake Huron's Chinook salmon population respond to the current lack of prey (will mechanisms emerge that control recruitment or survival, will disease epizootics and malnutrition cause adult mortality to rise)?; and, Will the collapse of alewives prove to be beneficial to recovery and sustainability of native species such as percids, lake trout, and lake herring? While Lake Michigan's alewife population appears to be relatively robust compared to Lake Huron, the increase in recreational catch rates and reduced ration indicate that current predator levels in Lake Michigan may not be sustainable. We recommend to the lake committees for both lakes Huron and Michigan that these results be used to update the management strategies for Chinook salmon in terms of the changing predator-prey relationships and ever changing food web.

To achieve Fish Community Objectives for certain native species, alewives may need to be suppressed to near the levels reached in Lake Huron. Yet, our experience to date suggests the Chinook fisheries we have become accustomed to during the last 20 years require higher alewife densities. Management strategies that target optimal production of salmon while suppressing alewives to a level consistent with native species recovery needs may not be achievable. Lake Huron's alewife collapse was accompanied by record year classes of both yellow perch and walleyes in Saginaw Bay and exceptionally large catches of age-0 wild lake trout in most areas of the Main Basin. The Lake Huron experience suggests that recruitment of native species may be suppressed by relatively low numbers of adult alewives; the large percid year classes appeared only after adult alewives had become almost absent from Lake Huron.

The LHTC and SWG will continue to monitor the growth and condition of Chinook salmon. Of particular interest is whether the Lake Huron Chinook population will succumb to malnutrition or stress-mediated disease such as BKD or furunculosis. In addition, we will continue to use the compiled data in predictive models to evaluate implications of measured trends and evaluate possible management strategies for predator species in the two lakes. In several cases, though, we have identified where data has only recently been collected or is not available (e.g., natural reproduction, diets, health monitoring, forage fish dynamics). Continued inter-agency commitment is necessary to assure that collection and assessment needs are met for Chinook salmon in lakes Huron and Michigan.

One key SWG parameter is contribution of natural reproduction to total Chinook salmon recruitment. All Chinook salmon stocked into lakes Michigan and Huron were marked, either with OTC (U.S.) or with fin clips (Ontario) from 2000-2003. However, there presently is no agreement among agencies as to a marking strategy that would permit continued monitoring of lakes-wide reproduction rates. Therefore, future monitoring will not include lakes-wide reproduction estimates until systematic marking is resumed. It is strongly recommended that the Lake Huron and Lake Michigan Committees implement an interagency marking program for all Chinook stocking so that monitoring of reproduction can resume. It is our belief that reproduction in Lake Huron was a leading factor precipitating the collapse of adult alewife stocks and that monitoring of reproduction is vital to our understanding of predator-prey balance in the two lakes.

Ultimately, management plans, objectives, and strategies need to be drafted for Chinook salmon by the lake committees to help guide the decision process. The Fish Community Objectives for both lakes call for rehabilitation of native species and state that suppression of alewives and smelt may be necessary to achieve native species recovery goals. At the same time, it must be recognized that healthy Chinook populations are vital to achieving and maintaining alewife control, at least until recovery goals for native predators are met. Defining (through the planning process) the relative importance of the two potentially conflicting goals of suppression of nonnative prey and maintaining healthy Chinook populations will help to further refine and focus Chinook salmon management, research, and assessment efforts.